Solar Hydrogen Project at Neunburg vorm Wald, Germany

SWB
A member of the Bayernwerk Group

Generating electricity in fuel cells

Demonstration of electric forklift truck powered by fuel cell plant

Three different types of fuel cell plant have been tested at the SWB facility atNeunburg vorm Wald, Germany. Once the major startup problems were overcome, experience with a stationary phosphoric acid fuel cell plant has turned out quite positive. At the present time an electric forklift truck powered by a solid polymer fuel cell plant is in test operation. Although the power output is rather limited, the truck is employed also to good effect for practical material handling duties at the site. An alkaline fuel cell plant proved to be overly sensitive.

Producing electricity from hydrogen

Heat, cold and motive power are not all that can be derived from hydrogen. It is usable to generate electrical energy as well. This is done in a fuel cell, in which hydrogen is electrochemically converted with oxygen to give water, producing electricity and heat in the process. Theoretically this is the reverse of water electrolysis.

The fuel cell principle was first demonstrated in 1839 by William Grove, a Welsh magistrate and friend of Michael Faraday. It consists in hydrogen combining with oxygen to form water by an electrochemical reaction rather than by combustion. The process is initiated by a catalyst and generates electricity with heat as a byproduct. Faraday's discovery of electrical induction, enabling electrical energy to be generated by the dynamo, led to development work on fuel cells being set aside at the time.

Systematic research was taken up in Germany in the 1950s with the alkaline fuel cell, which was the basis for construction of workable systems delivering up to 100 kilowatts of electrical output. Development moved sharply forward in the next two decades with the emergence of space travel, where the fuel cell is an optimum source of energy.

It is only more recently that work on fuel cells has been pursued more vigorously and substantially accelerated by progress in materials research. While the technical breakthrough leading to widespread commercial application has still not come about for this technology, demonstration plants on a larger scale have been realized for all types of fuel cell. One or the other type is sure to reach the market in the years ahead.

The underlying principle

Stated simply, a fuel cell may be likened to a battery that is continuously recharged. The cells of a normal battery, disposable or rechargeable, are discharged when the chemical energy combined in their solid "fuel" is used up. If new chemical energy is supplied to the battery, however, electrical energy can be taken from it at the same rate. This is what happens in a fuel cell by feeding hydrogen and oxygen to it. In principle a fuel cell plant can operate with a variety of fuels, for instance natural gas, methanol, propane, butane or gasoline. The hydrogen ultimately required to liberate energy in the cell is produced from these fuels in a reformer ahead of the inlet. Oxygen needed in the conversion reaction may be obtained from the ambient air or fed direct to the cell.

The chemical reaction taking place in a fuel cell is substantially clean in regard to emission of pollutants. Small emission levels occur only when the fuel is reformed but are still very minor compared to other energy converters.

Chemical conversion produces free electrons

A key feature of every fuel cell is the electrolyte separating the two electrodes, anode and cathode, and with them the two feed gases. Different types of fuel cell are often designated by the electrolyte used. Both electrodes are coated with a catalyst. The fuel cell reaction is initiated by feeding the fuel, for example hydrogen, to the anode and the oxidizer, oxygen or air, to the cathode.

Ions, that is electrically charged particles, and electrons form due to the catalytic action of the electrodes. Electric current flows by closing the circuit through an externally connected load. The heat generated by the reaction also lends itself to use. When using hydrogen as the fuel gas, pure water is formed by the reaction.

The fuel cell is in other words an energy converter simultaneously generating direct current and heat.

Types of fuel cell

Different types of fuel cell result from the combination of materials. A major distinguishing factor that also affects potential application of the cell is the operating temperature. Distinction is usually made between low-temperature (80 to 200 degrees Celsius) and high-temperature (650 to 1,000 degrees Celsius) fuel cells. Low-temperature fuel cell plants are particularly suited for mobile applications, other systems more for stationary service.

With rising temperature, the demands placed on quality of the fuel supplied generally decline. On the other hand, high temperatures are accompanied by higher specifications for the materials of construction. Technical maturity is for the most part more advanced in the low-temperature systems.

Large number of cells

The fuel cell is the active portion of the electrical energy source. As a single cell produces no more than typically 0.5 to 0.8 volt of direct current, several cells are required in series to obtain a useful voltage. The simplest arrangement of cells is in vertical stacks, which are in turn connected in parallel or series to further increase the output, resulting in a modular assembly comprising a large number of cells. Devices to take off the current and dissipate the heat of the reaction are also needed and provision must be made for supplying the fuel and oxidizer and discharging the reaction products. Peripheral equipment controls operation of the complete fuel cell plant and converts the direct current to alternating current.

Operating experience at SWB

Three different fuel cell plants were tested and compared at the Neunburg vorm Wald facility. The separate types are suitable for different applications. A phosphoric acid fuel cell plant working at around 190 degrees Celsius and exporting the generated heat at 165 degrees Celsius performed well as a stationary system for electricity generation and waste heat utilization. An alkaline fuel cell plant requiring oxygen for the oxidizer proved overly sensitive and was finally shut down in 1994.

A solid polymer fuel cell plant with an operating temperature of 60 degrees Celsius has demonstrated its suitability for mobile applications. A 10 kilowatts system of this type powers a modified standard production model of an electric forklift truck at Neunburg vorm Wald. The hydrogen fuel for the fuel cell plant is stored on board the truck in metal hydride, the supply lasting for about eight hours of operation.

In a running cycle simulation set-up, this fuel cell plant is loaded and tested at randomly programmable rates. This particular fuel cell technology proved to be fundamentally predestined as an electrochemical source of energy for electric vehicles.